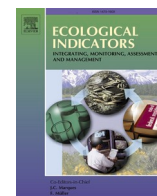


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Assessing the impact of individual nutrition on biodiversity: A conceptual framework for the selection of indicators targeted at the out-of-home catering sector

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ABSTRACT

Agriculture is an economic sector with massive impact on biodiversity and agrobiodiversity. Sustainable diets represent a critical policy leverage and a realistic opportunity to reduce the environmental impact of the agro-food sector while improving human health at the same time. Eating out is an increasingly common habit for many consumers and, by offering sustainable dishes, catering companies can play a central role. To do this, they need to understand and correctly assess the sustainability of their food portfolio, but assessment tools are not well established yet. The NAHGAST project, of which this study was part, developed and tested a sustainability assessment tool for catering companies based on concrete targets defined per meal. This study addresses the lack of methods to evaluate the impact of food on biodiversity, with a particular focus on agrobiodiversity. The work illustrates a context-specific application of an enhanced DPSIR model to structure information and select indicators, and proposes a transdisciplinary use of existing metrics. Further research is needed in order to define scientifically sound target values or sustainability ranges for each indicator per meal, in order to calculate them. Strengths and limits of the study are discussed.

1. Introduction and research questions

Eating sustainable meals could importantly contribute to more biodiversity protection and sustainability (Garnett et al., 2014; IPBES – Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services, 2019; Stoll-Kleemann and Schmidt, 2017). This work presents a theoretical framework that was developed, on the base of the Driving force-Pressure-State-Impact-Response (DPSIR) chain, with the purpose of a) conceptualizing the relation between individual food consumption in the out-of-home sector and biodiversity (with a particular focus on agrobiodiversity¹); b) selecting indicators to assess this. Established and practice-oriented instruments to evaluate the biodiversity-related implications of food are currently missing (GNF, LCF – Global Nature Fund, the Lake Constance Foundation, 2017). Yet,

in the light of the ongoing biodiversity crisis and the critical role played by food production and consumption, they are essential to individuate potential for improvement and priorities for action.

The study was realised as part of the research project NAHGAST², which developed and tested an assessment tool enabling out-of-home catering companies to measure and improve the sustainability performance of their food offering (Engelmann et al., 2018). Research in this field is quickly growing but, still, open questions remain. This work asked the following:

- i. How can the influence of a meal on biodiversity be conceptualized and operationalized? Which dimensions should be included in such an assessment?

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¹ Since most of the ingredients included in the meals assessed with the NAHGAST tool were plant-based and because of resource constraints, this study focused especially on crops biodiversity.

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- ii. Which indicators exist to assess the impact of food (production and consumption) on biodiversity?
- iii. Which of them could be used to assess the impact of single meals?

The first step to answer these questions was the development of a theoretical framework to conceptualize the issue. The nexus between food consumption and biodiversity loss is *mediated* by food production and thus indirect. For this reason, understanding and visualizing how our dietary choices affect biodiversity is important and might be not immediate. The relation between food and biodiversity is explained in [Section 2](#), followed by the study materials and methods in [Section 3](#). The theoretical framework proposed in order to individuate the dimensions to include in the assessment and provide a rationale for indicators selection is presented in [Section 4](#), while in [Section 5](#) potential indicators are analysed. The final set of recommended measures is found in [Section 6](#); [Section 7](#) discusses strengths and limits of the analysis and issues left open.

2. Biodiversity, food and the role of the catering sector

2.1. Biodiversity is essential for food and agriculture

Biodiversity comprehends the “variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part”, including “diversity within species, between species and of ecosystems” (CBD, 1992, p. 3). It is essential for sustainable food systems and healthy diets, as it can be linked to agriculture and nutrition at three different levels: at a macro level, as it underpins those ecosystem services (ES) agricultural production relies upon; at a farm level, as it is essential for productivity, stability, resilience and the overall sustainability of agro-ecosystems; and at dietary level, as agricultural diversity is fundamental for dietary diversity and human health (Berti and Jones, 2013; Burlingame, 2012; Fanzo et al., 2013; Heywood, 2013; Hodgkin and Hunter, 2015). The variety and variability of living organisms that form an agro-ecosystem and are involved in food and agriculture (both organisms purposely used for agricultural production and those outside of production systems and which benefit, depend on or are affected by farming practices) is called agricultural biodiversity, or agrobiodiversity (Heywood, 2013; CBD, 2000). Agrobiodiversity, too, can be seen as organized on different levels interacting with each other: habitat/landscape diversity, spacing from intensively managed farmland to extensively managed semi-natural habitats; species diversity, of both domesticated and wild species, which depend on or benefit agro-ecosystems; and genetic diversity, the richness of gene variations among individuals within a species, essential for the evolution of species and populations, their ability to adapt to changing environmental conditions, and thus for agro-ecosystems stability and resilience, food production and security, and cultural identity (Landis, 2017; FAO, 2015; Jeanneret et al., 2012a, 2012b; Last et al., 2012; Dennis et al., 2009). A peculiarity of agrobiodiversity is that of being greatly shaped by human activities, as it also includes socio-economic and cultural elements such as the knowledge related to (local) resources and how they are managed and used (Gold and McBurney, 2012; CBD, 2000). Agrobiodiversity comprehends also those living organisms and abiotic factors not directly managed by humans and providing ES such as nutrient cycling, soil fertility, pest and disease control, pollination, climate regulation or carbon sequestration. On the one side, farming practices can contribute to the conservation of biodiverse agro-ecosystems and management of biodiversity in a sustainable way to support, maintain or enhance ecosystems functions. On the other side, several agriculture-related ES are declining, mostly because of intensive farming practices and inappropriate management (Emmerson et al., 2016). Agriculture is one of the economic sectors with the largest impact on biodiversity, and the intensification, specialization and standardization of production, on which modern food systems are based, have led to a simplification of

agrobiodiversity on all levels (Emmerson et al., 2016; Landis, 2017). This is very dangerous not only for the ecological resilience of agro-ecosystems, but also for food security and human health and well-being (FAO, 2018; Garnett et al., 2014; Heywood, 2013).

Public understanding and appreciation of biodiversity, the promotion of sustainable forms of agriculture and the commercialization of landraces and traditional domestic animal breeds need to be increased (FAO, 2010; IPBES – Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services, 2019). The conservation, commercial cultivation and use of the greatest possible agrobiodiversity are the best approach for its long-term preservation (BMUB – Bundesministerium für Umwelt, Naturschutz, Bau und Reaktorsicherheit, 2007).

2.2. The importance of the out-of-home catering industry

Since “what, and how much we eat directly affects what, and how much is produced” (Garnett et al., 2014, p. 4), sustainable diets represent a crucial policy leverage and a realistic opportunity to reduce the environmental impact of the agro-food sector while improving human health at the same time (Lang and Barling, 2013; Speck et al., 2017). The NAHGAST project, of which this study was part, focused on the out-of-home catering sector, based on the fact that eating out has become a common daily habit for many people. Out-of-home catering includes public procurement and institutional food services such as school and hospital canteens, work-place-gastronomies, hotels, gourmet restaurants, fast-food chains, takeaway, coffeeshops etc. In the EU, one in four meals is now consumed outside of home, one in two at the workplace (FERCO – European Federation of Contracting Catering Organisations, 2020); in Germany, out-of-home catering is the second most important food distribution channel after food retailing (Speck et al., 2020). Only 40% of the population cooks every day (BMEL – Bundesministerium für Ernährung und Landwirtschaft, 2019) and in 2018 the German industry recorded around 11.8 million customers per day (excluding health facilities). The number of meals consumed at home decreased by 3 billion between 2005 and 2015 and, due to socio-economical developments, the sector is expected to increase to 40% of food sales in Germany over the next few years (Speck et al., 2020). Moreover, settings such as school or workplace canteens have the potential of influencing the nutrition-related behaviour of an increasing share of consumers on the long term. By offering sustainable meals culturally acceptable, affordable and accessible, the out-of-home gastronomy could thus make a significant difference. Factors that primarily affect the sustainability of the sector include inefficient and complex supply chains, product quality (e.g. conventional, organic or local food), consumer behaviour (e.g. regarding meat consumption) (Speck et al., 2020; Langan et al., In publication). Options to influence the sustainability impact of canteens exist at both the demand and the supply level, e.g. by acting on cooking processes and recipes; this scale is object of the present work.

2.3. The NAHGAST online assessment tool

Catering companies thus need practice-oriented, sound and as far as possible standardized instruments, in order to evaluate the sustainability of their food offering and to individuate priorities for action. NAHGAST developed and tested an assessment tool for companies to enable them assess the sustainability performance of their offered menus (see [Table 1](#) below) (Engelmann et al., 2018). The tool, based on the *Nutritional Footprint* (Lukas et al., 2016), is available online for free³; it was launched in March 2018 and so far >1500 analyzed meals have been registered. (Speck et al., 2020).

The biodiversity indicator was included in the development of the NAHGAST-tool because of its high relevance but, because of lacking data and methodologies, was not calculated yet (Speck et al., 2017). In

³ Available at www.nahgast.de.

Table 1

Indicators and sustainable levels applied in the NAHGAST online assessment tool (Speck et al., 2020).

| Indicators and sustainability targets/tolerance ranges per meal* | Dimension | Social | Health | Economic ¹ |
|--|---|---|--|---|
| | Environment | | | |
| | Material Footprint (<2670 g/<4000 g/>4000 g) | Share of fair ingredients (>90%/. >85%/ <85%) | Energy (<670 kcal/<830 kcal/>830 kcal) | Popularity (without quantified target value) |
| | Carbon Footprint (<800 g/<1200 g/>1200 g) | Share of animal- based foods that promote animal welfare (>60%,/>55%/ <55%) | Fat (<24 g/ <30 g/ >30 g) | Cost recovery (without quantified target value) |
| | Water use (<640 L/ <975 L/>975 L) | | Carbohydrates (<90 g/ <95 g/ >95 g) | |
| | Land use (<1.25 m ² /<1.875 m ² />1. 875 m ²) | | Sugar (<17 g/ <19 g/ >19 g) | |
| | | | Fibres (>8 g/ > 6 g/ <6 g) | |
| | | | Salt (<2 g/ <3,3 g/>3,3 g) | |

*Recommendable/Limited recommendable/Not recommendable.

¹The dimension economy is currently not included in the online tool, mainly because of data availability. Both cost recovery and a certain popularity of the dishes were assumed in the catering facilities examined (Speck et al., 2020).

general, to evaluate the biodiversity impact of a product, its value chain has to be analysed. Methodologies such as the Life Cycle Assessment consider biodiversity mostly in terms of Mean Species Abundance (PBF – Product Biodiversity Footprint, 2017). Further indicators often adopted include Land-use and Ecological, Carbon and Water Footprints. These metrics, however, do not specifically focus on food-related biodiversity, do not account for its socio-cultural implications and, in NAHGAST, are already used to calculate the ecological impact of a meal.

3. Material and methods

3.1. Literature search

Primary searches were conducted on ScienceDirect, Scopus, Web of Science and Google Scholar; the authors also had access to information and data generated in NAHGAST. Documents and contents published in English, German and Italian were considered, as these are the languages fluently spoken by the leading author. Peer-reviewed journal articles, books, book chapters and grey literature were accepted, with a preference for works published in the last ten years. Websites were considered only from trusted sources. The information obtained was compared in order to individuate similarities, differences and eventual inconsistencies; the first screening and reading of the literature allowed for a fine-tuning of the further search. The process was repeated until a point of saturation was reached and it could be concluded that works not identified would have not fundamentally changed the findings. However, since it is impossible to know which studies have not been considered, the consequent uncertainty must be acknowledged. Categories and sub-categories were used to cluster and organize the information found (Mayring, 2014). About 50 indicators, indexes and concepts were identified and compared, and about 30 were selected for further analysis. The steps taken to individuate the final indicator set were based on the Indicator Development Framework of the Biodiversity Indicators Partnership (BIP – Biodiversity Indicators Partnership, 2011).

3.2. Indicators selection criteria

Indicators were chosen according to criteria listed in Table 2. To improve their usefulness and actual adoption, the inclusion of stakeholders' perspectives in their development process is recommended (Dennis et al., 2009; EEA – European Environmental Agency, 2014). In NAHGAST, this was done through a series of workshops with experts and representatives of catering companies. They made clear that the assessment tool should have been practice-oriented, readily understandable, based on data easily accessible and easy to compute for trained kitchen staff without external support (Speck et al., 2017).

Table 2

Indicator selection criteria used in this study (source: own work).

| Criteria | Specification |
|---|--|
| Scientific soundness | <ul style="list-style-type: none"> Underlying methodology: sound, clear, relatively simple Relevance and suitability for addressing an issue recognized by the scientific literature |
| Relevance and usefulness for target audience | <ul style="list-style-type: none"> The indicator meets real needs and interest of users It supports decision-making (i.e. it enables monitoring and helps individuate the best goals/measures). Therefore: i) it is applicable at the required scale (single ingredients/meals); ii) it refers to reference values or goals; iii) it shows in which direction it should develop to improve |
| Understandability and communicability | <ul style="list-style-type: none"> The indicator is not based on too abstract or complex concepts It refers to scales/units users and the public can easily understand The final indicator set includes a limited number of metrics |
| Practicability(i.e. measurability and feasibility in context) | <ul style="list-style-type: none"> The indicator is simple to apply in the context of daily kitchen operations It is measurable in a cost-effective way It is based on quality, accessible data |

4. Theoretical framework

4.1. Conceptual models for indicators selection

The underlying rationale of indicators is the explanation, communication, monitoring and/or assessment of a phenomenon through one or a set of measurable parameters that aggregate data (Wu and Wu, 2012). Indicators quantify and simplify phenomena by operationalizing specific attributes through quantitative or qualitative variables, synthesizing information and reducing the number of measurements and factors necessary to represent them (Heink and Kowarik, 2010). The definition and selection of indicators depend on their purpose and always involve choices related to values and priorities, since they are based on just certain aspects of a phenomenon – those considered relevant by the indicators producers or users, or those on which data are available (Duelli and Obrist, 2003; Pereira et al., 2013). Limitations can be due to an issues complexity, data availability and quality. As in the case of biodiversity, it may not be possible to directly measure a phenomenon, or to do this at the level of detail appropriate for the decisions that have to be taken. Moreover, it can not be expected that indicators will significantly contribute to better decisions simply by providing information, as communication alone is generally not enough to ensure that knowledge is also used. Yet increasing stakeholders and public

awareness and management capacity can potentially trigger change (Bauler, 2012). Conceptual frameworks generally represent the base for an indicator set. They link indicators to a theory, guide the selection process, support the development of a narrative putting indicators in context and within a broader perspective, facilitate the comprehension and communication of an assessment (Sébastien et al., 2014). Conceptual frameworks are thus critical for structuring complex issues. They help visualize linkages between systems components, identify key processes and facilitate the explanation of complex interactions (BIP – Biodiversity Indicators Partnership, 2011; EEA – European Environmental Agency, 2014).

4.2. Proposing a framework relating biodiversity and food consumption in catering settings

To structure and clarify the (indirect) relationship between food consumption and biodiversity, a conceptual framework was developed. Binder et al. (2013) have shown a comparison of conceptual models for the analysis of social-ecological systems. Most of the environmental assessments currently realized relies on the Driving force-Pressure-State-Impact-Response (DPSIR) framework. This model is structured around the interplay between Driving forces (D), Pressures (P), States (S), Impacts (I) and Responses (R) (see e.g. Buiteveld 2009). The DPSIR framework is action-oriented, allows a systems analysis perspective and provides a structure supporting the transdisciplinary development of indicators and placing them in context (Hou et al., 2014; Binder et al., 2013; Ness et al. 2010). For these reasons, it is commonly adopted in biodiversity assessments to clarify which anthropogenic processes determine certain pressures and which measures may be implemented to reduce them (Hou et al., 2014). On the other hand, the DPSIR framework has been criticized for focusing mainly on social-economic factors, disregarding the ecological ones. It has also been argued that the model focuses on pressures and marginalizes their underlying drivers (Binder et al., 2013; Cumming, 2014), and that its causal chain logic is too simplistic and linear (Tscherning et al., 2012).

The framework proposed in this study (Fig. 1) is a slightly modified version of the DPSIR chain, enhanced with elements of the Millennium Ecosystem Assessment (MEA) conceptual framework, partially based on the DPSIR model as well. The MEA framework highlights the importance of biodiversity for human health and wellbeing and the complex relationships between human and environmental systems (MEA – Millennium Ecosystem Assessment, 2003). As it becomes clear, the nexus between food consumption and biodiversity loss is mediated by food production and thus indirect. This is important, as in consequence understanding and visualizing how our dietary choices affect biodiversity might be not immediate. The model depicted in Fig. 1 (based on the DPSIR and the MEA representations) was developed to clarify this connection, in order to individuate the dimensions to include in the assessment and provide a rationale for indicators selection. The framework includes both elements of the DPSIR and of the MEA models, as the relationship between biodiversity and human wellbeing is made explicit. Even though the DPSIR-chain was first conceived to conceptualize social-ecological systems on a macro level (Binder et al., 2013), different authors have shown its usefulness for analysis at smaller scales (see e.g., Binimelis et al., 2009). Maes et al. (2016) have shown how to combine different biodiversity-related conceptual frameworks. Kelble et al. (2013) have proposed a version of the DPSIR that integrates ES in order to emphasize the complex interdependencies between the human and the ecological system. Kuldna et al. (2009) have applied the DPSIR framework to analyse pollinator loss, and Buiteveld et al. (2009) have applied the MEA to genetic agrobiodiversity. Additionally, in the present study the DPSIR chain explicitly considers also stakeholders responses, as the work seeks to show not only how catering companies affect biodiversity, but also how they can act to promote its protection.

As Fig. 1 shows, the food offered by catering companies can be considered an *indirect Driver* of biodiversity loss. It is determined by

factors such as the human need for food, products availability and consumer demand. Consumers' preferences, in turn, are influenced by multiple elements such as taste, trends, willingness to pay and socio-economic status, and result in the demand for products with specific price and quality-related features (Kearney, 2010). The demand for food (Driver) determines Pressures on the environment through agricultural production – and agriculture directly affects ecological conditions and biodiversity (Emmerson et al., 2016; FAO, 2010). Different farming practices affect the environment in different ways, can promote biodiversity conservation or not, and ultimately result in different agro-ecosystems characterised by diverse conditions. These Pressures influence the State of the environment, i.e. the biophysical characteristics, structures and processes of ecosystems, which are the base for the provision of ES and food production. Agriculture affects biodiversity both within and outside agro-ecosystems. Changes in biodiversity state have then an Impact on ecosystems functioning, altering the provision of ES with consequences for human health and wellbeing (Santos-Martín et al., 2013). For example, a decline in pollinators due to land-use change and habitat loss reduces the services they provide and might decrease the productivity of agro-ecosystems. As a consequence, certain products might become less available and more expensive (Goulson et al., 2015). At this point, stakeholders can implement measures to prevent, compensate, contrast, improve or adapt to the changes described. Policy Responses include measures such as the promotion of sustainable farming practices through regulations or economic incentives, the introduction of certification schemes, programs promoting the on-farm conservation and consumption of agrobiodiversity. Catering companies can support agrobiodiversity conservation by acting on their supply chain (e.g. by employing organic foods) and by producing meals that promote the consumption of food variety.

4.3. Dimensions included in the assessment

Based on this analysis, it can be argued that meals indirectly affect biodiversity in two ways:

- i. through the agricultural production methods of their ingredients;
- ii. through the foods they are made of (e.g. if a certain dish contains less-used crop varieties or not).

Production methods and variety of food in a meal are hence the two dimensions that were considered for the definition of the NAHGAST indicator “Influence [of a meal] on biodiversity”. Indicators to assess the impact on biodiversity of agricultural production and consumption of dietary variety were thus investigated. These two dimensions were suggested also in a workshop with experts held in 2015.

5. Indicators to assess the impact of single meals on biodiversity

5.1. Biodiversity indicators

Biodiversity indicators represent a subset of environmental indicators that measure states, changes, trends and dynamics of a certain environment (States and Impacts) or of the human activities affecting it (Drivers, Pressures and Responses) (Blauvelt, 2014; Heink and Kowarik, 2010). Developing such indicators is particularly challenging because biodiversity has no established operational definition and cannot be measured *per se*. Nevertheless, some of its components can act as proxies and, by monitoring one or more suitable features over time, estimations are possible (Buiteveld et al., 2009; Duelli and Obrist, 2003; Parr et al., 2010).

5.2. Indicators related to the impact of agricultural production on biodiversity

The indicators considered for assessing the impact of agricultural

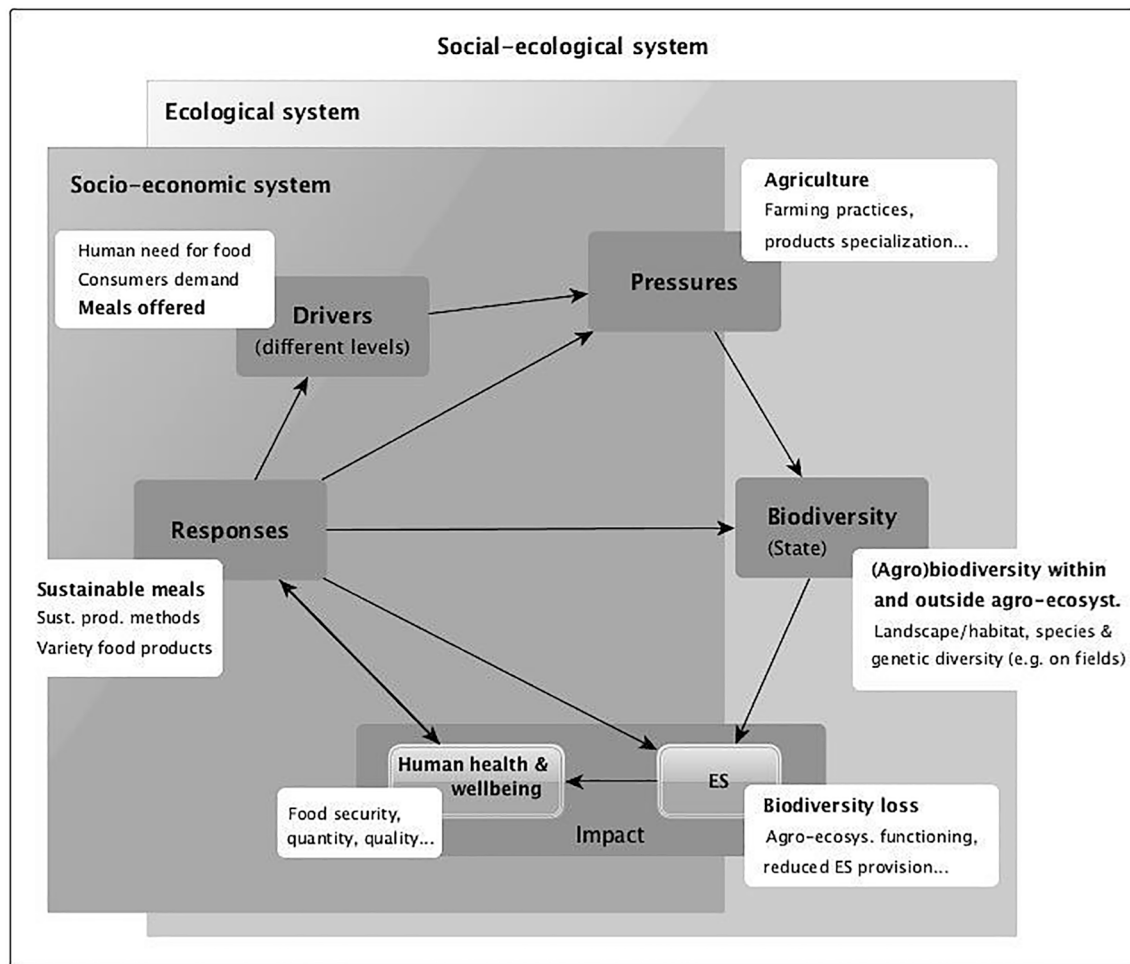


Fig. 1. The DPSIR framework developed for this study to clarify the connection between meals offered in out-of-home catering settings and agrobiodiversity (highlighted in the white boxes; source: own work). The figure is based on the DPSIR and MEA representations and allows the identification of dimensions and indicators to include in the assessment. ES, the benefits underpinned by biodiversity that humans are provided by ecosystems, connect the social and the ecological dimensions, that together form the overall socio-ecological system.

production on biodiversity are listed in [Tables 5 and 6](#) (see Appendix). They include both direct indicators (based on observations, counts or estimates, for example the occurrence of a certain variety on a field) and indirect (related to farming methods and agricultural management practices, e.g. “nitrogen application” as proxy for farming intensity) ([Arndorfer et al., 2012](#)).

5.2.1. Landscape/habitat diversity

Composition, structures, features, type and combinations of agricultural landscapes determine the conditions for and affect species diversity. A mosaic of different habitats generally increases biodiversity; many ES and ecosystem processes depend on the possibility for organisms to move across a landscape. Habitats connectivity as well as complexity and heterogeneity of spatial structures are thus particularly significant ([Bailey et al., 2012](#); [Bunce et al., 2013](#); [Dennis et al., 2009](#); [FAO, 2015](#); [Landis, 2017](#)).

5.2.2. Species diversity

The underlying rationale of a species indicator is that, by protecting a certain species, other living in the same ecosystem can be safeguarded as well ([Hoffmann and Greef, 2003](#)). Flowering plants of semi-natural habitats, for example, may indicate diversity of other organisms, as plant species richness seems to significantly influence ecosystem processes at lower levels ([Dennis et al., 2009](#)).

For the diversity of domesticated species, the species and ecosystem

levels are less relevant, as increases in the number of crop species farmed can be due to the introduction of exotic (alien) species ([Bunce et al., 2013](#); [Eaton et al., 2006](#)). Even though more diverse crops generally indicate more biodiversity and diversification in the structure of an agro-ecosystem, species richness or diversity indicators do not provide information about the identity of the species considered – but different species in different contexts do not have the same conservation value. It is hence important to focus on species characteristic and critical for the biodiversity of a certain ecosystem ([Eaton et al., 2006](#); [Hoffmann and Greef, 2003](#); [Overmars et al., 2014](#)).

5.2.3. Genetic diversity

Agro-ecosystem where multiple cultivars are grown appear to be more stable, resilient and productive ([Di Falco and Perrings, 2003](#); [Hajjar et al., 2008](#)). Accounting for this aspect is critical also because different varieties have different nutritional significance (substantial differences exist in the nutrient composition of different cultivars of the same crops); moreover, if varieties become more related to each other, genetic diversity within them might decrease even though their number

and shares do not change⁴ (Last et al., 2012). Genetic diversity, however, can be precisely measured only with molecular markers. Indicators such as the “number of varieties” are thus considered indirect measures (Brown and Hodgkin, 2015).

5.2.4. Farm management

These indicators measure the level of farming intensity, i.e. the pressure exerted on an agro-ecosystem by agricultural practices and determined by the level of inputs and outputs of an agricultural system (Arndorfer et al., 2012). Land use and its intensity affect biodiversity not only at the farm/plot level (e.g. grazing intensity), but also at larger spatial scales (e.g. habitat fragmentation and loss) (Arndorfer et al., 2012; Bailey et al., 2012). “Organic farming” is suggested by different studies as a proxy indicator in the absence of more specific metrics. Organic farms are often characterized by a greater complexity of landscape and crop structure, greater species diversity and a higher variety in the crops sown. However, even though organic agriculture seems to have positive effects on biodiversity, studies results are not always univocal (Crowder et al., 2010; Dennis et al., 2009; Norton et al., 2009). For this reason, some authors do not recommend the use of this indicator (Arndorfer et al., 2012).

5.3. Indicators related to the impact of diets on biodiversity

Reliable ways to measure and monitor diversity across diets are currently not available because of missing data (Lachat et al., 2017; FAO & BI, 2017). Yet the importance of maintaining traditional and wild species both in agricultural production and in consumption is acknowledged (Lachat et al., 2017). Indicators currently being developed include species diversity scores or richness of species by food group consumed. For the moment, however, these metrics are not established and Dietary Diversity scores, which measure how many food groups an individual or a household consume over a certain period of time, are often used as a proxy for variety consumption (see Table 6 in the Appendix) (El Bilali et al., 2017; FAO & BI, 2017).

5.4. Food labels and standards including or based on specific biodiversity-related criteria

The following food labels, relevant for Germany, include or are based on criteria specifically related to the conservation of (agro)biodiversity.

5.4.1. Organic labelling

Organic farming is based on practices that generally support biodiversity conservation and sustainable use – although, as mentioned before, studies results are sometimes not univocal. In the EU, food products that fulfil the regulations EC 834/2007 and EC 889/2008 are marked with the EU logo for organic products. In addition to this, over 30 organic food labels are used in Germany (BLE – Bundesanstalt für Landwirtschaft und Ernährung, 2013; IHK – Industrie- und Handelskammer Pflanz, 2013). They are owned, verified and awarded by different organizations (national/federal states, farmers associations, retail chains) and are based on partially different standards, ranging from the mere complying with the EU requirements to labels based on standards much stricter than the EU ones (Umweltinstitut, 2014). The standards applied by Naturland, Bioland and Demeter perform very well with regard to biodiversity conservation (WWF Switzerland, 2015).

⁴ Only landraces or non-hybrid varieties of allogamous species are considered to be genetically heterogeneous populations (Wetterich, 2003). The genome of many new varieties is often very similar to that of high production ones; if a new variety is bred that is almost identical to an already existing dominant one, the total share of both may increase at the expense of more actual diversity (Brown & Hodgkin, 2015, Padulosi et al. 2013, Buiteveld et al., 2009).

5.4.2. The ProSpecieRara label (PSR)

The Swiss Foundation *ProSpecieRara* has developed a label (*Gütesiegel*) specific for agro-biodiversity-friendly products. In Germany, the criteria that a crop variety must fulfil in order to obtain the special status of protected “ProSpecieRara variety” include: being commercially rare or not distributed at all; being particularly important for diversity conservation; having a German tradition or origin (if a traditional German crop variety is no longer available, a corresponding variety can be recognized as ProSpecieRara-worthy, even without a direct German tradition or origin). For Germany, the Foundation has developed a list of vegetables and cereals eligible for its label. For Switzerland, such list also includes fruits (wild or domesticated), berries and herbs (Bartha, 2012; ProSpecieRara, 2017). Gastronomies promoting the commercial use of one or more of such foods can obtain the *Gütesiegel* as well.

5.4.3. European Quality Schemes

The EU logos *Protected Designation of Origin (PDO)*, *Protected Geographical Indication (PGI)* and *Traditional Speciality Guaranteed (TSG)* refer to specific traditions and qualities of foods produced in the EU or in third countries, which have to be produced in a determined geographical area and using recognised knowledge and expertise (EC – European Commission, 2017). By valorising the relationship of certain products either to their region of origin or traditional production processes, these logos are particularly relevant for the socio-cultural dimension of agrobiodiversity. Human-environment interactions shape the cultural landscapes that characterize numerous regions (e.g. the vineyards in many French or Italian regions, or the alpine meadows typical of the Tyrolean area), creating so-called “terroirs” (Larson, 2007). They are fundamental for the management and preservation of local resources, and studies have shown that these labels can be a tool for valorizing and protecting them (Puzone, 2012).

5.4.4. Slow Food Foundation’s “Ark of Taste”

The online catalogue includes small-scale quality productions (fruits, vegetables, animal breeds, cheeses, cured meats, breads, sweets) that are: domestic species, wild species tied to methods of harvesting, processing and traditional uses, or processed products; of distinctive quality in terms of taste as defined in the context of local traditions and uses; linked to a specific area, to the memory and identity of a group and to local traditional knowledge; produced in limited quantities; at risk, due to fragile supply chains or environmental contexts. The *Ark* currently includes over 5400 food products (as of January 5th, 2020). For Germany, 74 products are listed, including e.g. apple and potato varieties, cattle and chicken breeds, and bread specialties⁵. Additionally, five products (such as the Swabian Alb Lentils) belong to the so-called *Slow Food Presidia*, a registered brand. Through the *Presidia*, the Foundation sustains quality production at risk of extinction, protects unique regions and ecosystems, promotes traditional processing methods and safeguards native breeds and local plant varieties⁶.

6. Analysis and results

6.1. The proposed indicator set

The indicators identified as relevant (listed in Tables 5 and 6 in the Appendix) were evaluated against the selection criteria; the analysis is presented below (Table 3). From this, a restricted number of indicators could be recommended for being included in the NAHGAST tool (Table 4). The online assessment instrument already encompasses 13 indicators (Table 1) and thus it was important to select a small number

⁵ See <https://www.fondazioneSlowFood.com/en/what-we-do/the-ark-of-taste/> (accessed 05.01.2020).

⁶ See <https://www.fondazioneSlowFood.com/en/what-we-do/slow-food-presidia/> (accessed 05.01.2020).

Table 3

Indicators evaluation based on the selection criteria listed in Tab. 2 (source: own work). * = low; ** = medium; *** = high; t.b.d. = to be defined.

| Assessment dimension | Biodiversity level | Indicator (see list in Tabs. 4, 5) | Potential NAHGAST indicator(s) (Applied at the scale of single ingredients/meal; related targets, thresholds or minimum levels to be defined) | Selection criteria (see list in Tab. 2) | | | |
|----------------------|-------------------------------------|---|--|---|------------|-----------------------|----------------|
| | | | | Scientific soundness | Usefulness | Understand. & commun. | Practicability |
| Food production | Habitat/Landscape | Landscape complexity | Min. standards to be defined per farm.FAO (2013): unsustainability threshold if only<20% of the habitat areas on a farm are ecologically well connected.→ NAHGAST indicator: Share of ingredients from crops grown onfarms meeting requirements | *** | */** | * | * |
| | | Farm-scale habitat heterogeneity | | | | | |
| | | Ecosystem connectivity | | | | | |
| | | Habitat Richness | | | | | |
| | Species diversity | Habitat Diversity | Min. standards to be defined per farm.→ NAHGAST indicator: Share of ingredients from crops grown onfarms meeting requirements | *** | */** | */** | * |
| | | Diversity and abundance of key species | | | | | |
| | | Crop species richness | | | | | |
| | Genetic diversity | Number of vascular plants species per farm | Min. standards to be defined per farm.FAO (2013): at least 50% of cultivated land being used for locally adapted, rare or traditional varieties; at least 50% of production accounted for by locally adapted/ rare and traditional varieties or from other than the most common genetic lineage; non-utilized plants grown on at least 5% and no<1% of a farm's land, with a high taxa diversity.→ NAHGAST indicator: Share of ingredients from crops grown on farms meeting requirements/originating from landraces | *** | */** | */** | * |
| | | Number of small wild animal species per farm | | | | | |
| | | Number and share of cultivars/landraces/varieties per species/farm | | | | | |
| Food consumption | Farm management | Share of production accounted for by locally adapted/rare and traditional varieties or from other than the most common genetic lineage | Min. standards to be defined per farm→ NAHGAST indicator: Share of ingredients from crops listed on oneof such Indexes/Share of ingredients from crops grown on farms meeting requirements | **/** | */** | */** | */** |
| | | Varieties grown that belong to the <i>Red List for European species</i> or the <i>Red List of Endangered Native Crops in Germany</i> | | | | | |
| | | Number of varieties grown characteristic for landscapes/production environments important for biodiversity and characteristic for a region or country | | | | | |
| | | Land-use intensity | | **/** | ** | ** | * |
| | Dietary diversity | Farm managed according to certified organic standards | Min. standards to be defined per farm.(2013): implementation on a farm of at least 20% of a list of possible measures to protect biodiversity.→ NAHGAST indicator: Share of ingredients from crops grown with low-, medium- or high- input | *** | **/** | *** | *** |
| | | Species conservation practices | Min. standards to be defined per farm→ NAHGAST indicator: Share of ingredients from crops grown onfarms meeting requirements | *** | */** | */** | * |
| | | Ecosystem enhancing practices | | | | | |
| | | Species conservation practices | | | | | |
| | | Wild genetic diversity enhancing practices | | | | | |
| | | Agrobiodiversity conservation on-farm | | | | | |
| | Dietary diversity | Genetic diversity in wild species | Nr. of food groups or food items, including cultivars, in a meal (minimum levels t.b.d.) Nr. of crop species/cultivars in a meal (minimum levels t.b.d.) Alternatively: Share of ingredients originating from less used/traditional crops | */** | */** | */** | */** |
| | | Dietary Diversity (food groups) | | | | | |
| | | Species diversity consumed | | | | | |
| Food production | Habitat/landscape/ speciesdiversity | Cultivar diversity consumed | Share of ingredients from a crop produced according to organic standards | *** | **/** | *** | *** |
| | | Organic labelling | | | | | |
| | Species/genetic diversity | <i>ProSpecie-Rara</i> label/Slow Food <i>Ark of Taste</i> list | Share of ingredients marked with the <i>ProSpecie-Rara</i> label/belonging to a <i>ProSpecie-Rara</i> list/to the Slow Food <i>Ark of Taste</i> list | *** | **/** | */** | **/** |
| | | <i>Bee Friendly</i> label | | *** | **/** | **/** | *** |
| Food consumption | Socio-cultural diversity | European Quality Schemes | Share of ingredients marked with PDO, PGI or TSG logo | **/** | **/** | **/** | *** |

Table 4

Proposed dimensions and metrics for the NAHGAST Indicator “Influence [of a meal] on biodiversity” (source: own work). Based on their positive or negative impact on agrobiodiversity, the metrics included can be seen as Pressure or Responses indicators in the DPSIR framework. Target-values per meal need to be developed.

| Indicator | Assessm. dimension | Biodiversity level | Specification |
|---|--------------------|--|--|
| Share of ingredients in a meal originating from farms implementing biodiversity-enhancing practices | Production methods | Landscape/habitat diversity, species diversity | As more precise data are generally not available, organic farming is taken as proxy for the impact of production methods. It should be taken into account that diverse organic standards have different implications for biodiversity. |
| Share of ingredients in a meal originating from underutilized/traditional/endangered crop varieties (when applicable) | Variety consumed | Species/cultivar diversity | The consumption of such foods supports their conservation on-farm. They should either be: i) marked with the <i>ProSpecieRara</i> label; or ii) belonging to the <i>German list of endangered crop plants</i> ¹ ; or iii) being listed in the <i>Ark of Taste</i> of the <i>Slow Food Foundation</i> . |
| Share of ingredients in a meal marked with a EU Quality logo (when applicable) | Variety consumed | Socio-cultural dimension of agrobiodiversity | Goal: maintenance of local/traditional knowledge, use and production processes of (local/traditional) resources. |

Available at <https://pgrdeu.genres.de/rlist?lang=en> (accessed 06.01.2020).

of metrics.

A relevant limitation is due to the fact that searches in the online assortment of major wholesale retailers showed that the data necessary to calculate many of the potential indicators were not available. Specific information about crops origin, variety and seeds quality can currently be provided just by a few smaller retailers specialised on organic products and working closely with local producers. Only indicators that could directly be implemented by catering companies are recommended. Indicators that would have been appropriate, but for which data are not readily available, are not suggested. Finally, we decided to take into account that diverse organic standards have different impacts on biodiversity (e.g. EU regulations/private labels of farmers organizations like *Demeter*; for a comparison (see [Janssen and Hamm, 2011](#); [Umweltinstitut, 2014](#)). Certifications schemes based on stricter regulations should be preferred wherever possible.

The proposed indicator set is thought not for being directly applied by kitchen staff in gastronomy companies, but for being included in the NAHGAST assessment tool. The online tool is designed to be user-friendly and is accessible to practitioners without external help from scientists. Our goal in this study was to individuate indicators suitable for being included in the instrument. Their fine-tuning, as well as the definition of scientifically sound target-values/tolerance ranges necessary to calculate the actual impact on biodiversity, need to be further investigated.

7. Discussion and outlook

7.1. Strengths and limits of the recommended indicators

Several indicators to assess the impact of agricultural production on biodiversity and agrobiodiversity can be found in the literature, while methods to consistently measure food variety across diets and indicators to specifically evaluate the impact of food consumption on biodiversity are missing. Comprehensive concepts have been developed to measure other aspects of food's sustainability, especially those related to material use, carbon emissions and nutritional values (e.g. the Nutritional Footprint, [Lukas et al., 2016](#)). Assessing and communicating the impact of a meal on biodiversity, however, is more difficult: operationalizing the concept is challenging, biodiversity needs to be assessed across different dimensions and levels and all-inclusive, readily understandable referring units such as CO_{2eq} cannot be defined. The absence of comprehensive, practice-oriented and sound assessments methodologies for the agri-food sector has been highlighted, and different international organizations and partnerships are currently working on assessment instruments and methodologies (see e.g. [GNF, LCF – Global Nature Fund, the Lake Constance Foundation, 2020](#); [GNF LCF, 2017](#)).

An important factor that limited the range of potentially feasible indicators was the lacking of data and aggregated indexes. Instruments to more precisely evaluate the consumption of food diversity are necessary. A more exact evaluation of the impact of farming methods should have been included in the assessment as well. Organic farming was chosen as a proxy, but measures more explicitly focused on the biodiversity implications of specific management practices would be preferable. The Swiss farmers association IP-Suisse has developed a logo (*Marienkäfer*, “ladybug”) that producers can obtain if they fulfil a series of requirements, many of which are specifically related to biodiversity protection. Studies have shown that the *Marienkäfer* can be considered a suitable proxy for the contribution of a certain farm to biodiversity conservation and for farm-level biodiversity. Another example of an aggregated metric is provided by Bio Suisse, the leading organization of Swiss organic producers and owner of the brand *Knospe* (“bud”). Farms producing goods marked with this logo must comply with numerous criteria, including a catalogue of 62 measures called “Biodiversity Check” ([Jenny et al., 2013](#); [Zellweger-Fischer et al., 2016](#)). The implementation also in Germany of such a monitoring system, translated into a label, would allow a better, more comprehensive and readily understandable evaluation of a food's biodiversity impact. Such a label could substitute the two dimensions “Organic” and “Organic according to guidelines stricter than the EU standards”. The role played by labels/certifications for biodiversity conservation and sustainable use still needs to be object of further studies ([Oehen et al., 2018](#)); a recent work found that ecological management performs much better than conventional agriculture with regard to water protection, soil fertility, biodiversity conservation, climate adaptation and resource efficiency ([Sanders and Heß, 2019](#); [BMEL – Bundesministerium für Ernährung und Landwirtschaft, 2020](#)).

Another issue needing further research is the fine-tuning of the indicators proposed in [Table 4](#). Target-values or sustainable levels for the indicators suggested in this work have to be developed, in order to calculate them at the scale of single meals. For some of them, [FAO \(2013\)](#) suggests figures that can be taken as reference. Also the empirical testing of the proposed indicators should be further investigated ([Oehen et al., 2018](#)). [Galli and Brunori \(2017\)](#) used the DPSIR-chain to select biodiversity and nutritional value indicators to qualitatively assess the performance of three Italian wheat-to-bread supply chains. The indicators chosen for evaluating the impacts on biodiversity (varietal diversity and presence of ancient varieties in flour, saving of seeds, on-farm management practices) are very similar to those recommended in this study, and thus corroborate its results. Finally, data availability to kitchen staff represents an important limit, as precise information e.g. about crop or breed varieties are often not available. And trade-offs

Table 5

Indicators to assess farmland- and crop-related biodiversity at the habitat/landscape, species and intraspecific level. Indicators' positioning in the DPSIR framework is indicated in brackets (D = Driver, P = Pressure, S = State, I = Impact, R = Response) (own work, [BI – Bioversity International, 2017](#); [BMUB – Bundesministerium für Umwelt, Naturschutz, Bau und Reaktorsicherheit, 2015](#); [Brown and Hodgkin, 2015](#); [Last et al., 2012](#); [Overmars et al., 2014](#); [FAO, 2013](#); [Arndorfer et al., 2012](#); [Bailey et al., 2012](#); [Hammer et al., 2012](#); [Jeanneret et al., 2012a, 2012b](#); [Buitemveld et al., 2009](#); [Dennis et al., 2009](#); [Eaton et al., 2006](#); [Wetterich, 2003](#)).

| Indicators | Biodiversity level | | | Farm management (P/R) |
|-------------------|--|--|---|--|
| | Landscape/Habitat diversity (S) | Species diversity (S) | Genetic diversity (S) | |
| <i>Indicators</i> | <i>Landscape complexity</i> <ul style="list-style-type: none"> Nr. of land-use types Share of non-crop habitat Share of farmland with semi-natural habitats Share of HNV farmland¹ Extent of European/regionally important habitats Extent of habitats related to particular ES (e.g. pollinators habitat) <i>Farm-scale habitat heterogeneity</i> (nr. and size of patches) <i>Share of well-connected habitats/farm</i> <i>Habitat Richness</i> (HR, the number of habitat types per ha) <i>Habitat Diversity</i> (HD, the heterogeneity of land-use types) | <i>Diversity and abundance of key species</i> (positive/negative: increases/decreases in diversity and populations of threatened/vulnerable species and decreases/decreases in invasive species populations) <i>Crop species richness</i> <ul style="list-style-type: none"> Nr. of crop species per farm or ha Nr. of crop species in rotation Share of high-diversity areas (where a diverse crop rotation and/or many species are grown simultaneously) in the total agricultural area Nr. of vascular plants species/farm Nr. of earthworms, spiders, wild bees, bumblebees, small mammals, amphibian, beetle and (rare) birds species/farm | <i>Nr. and share of cultivars/landraces/varieties per species per farm</i> (FAO sets the target of at least 50% of cultivated land being used for locally adapted, rare or traditional varieties) <i>Share of production accounted for by locally adapted/rare and traditional varieties</i> <i>Share of production from other than the most common genetic lineage, for each used species</i> (FAO sets the target of no>50%) <i>Crop varieties that belong to a Red List</i> (e.g. Index for European species, Red List of Endangered Native Crops in Germany) <i>Number of varieties grown characteristic for landscapes/production environments important for biodiversity and characteristic for a region or country</i> | <i>Land-use intensity</i> (farm type) <ul style="list-style-type: none"> Total input costs/ha Nitrogen application/ha Pesticides/fertilizers application/ha Share of agricultural area without application of agrochemicals <i>Farm managed according to certified organic standards</i> <i>Practices enhancing or harming managed and wild biodiversity</i> (agroforestry, mixed-farming, intercropping, integrated pest management, ecological infrastructures and habitat networks vs. monocultures, entire crop production based on a single genetic lineage, conversion of HNV land, heavy reliance on agrochemicals) <i>Agrobiodiversity conservation on-farm</i> |

¹ Indicators such as the “Share of farmland with High Nature Value” indicate the overall potential of a farm to support wildlife biodiversity. The concept of HNV was developed based on the fact that, in many European rural regions, biodiversity conservation depends also on maintaining traditional low-intensity production systems ([EFNCP, 2017](#)).

Table 6

Driver-indicators accounting for the diversity of food consumed in a diet at the species or variety level (own work, [Lachat et al., 2017](#); [BI – Bioversity International, 2017](#); [El Bilali et al., 2017](#); [Donini et al., 2016](#)).

| Indicators | Rationale/Description |
|--|---|
| <i>Dietary Diversity</i> (food groups) | Dietary diversity represents the number of individual food items or food groups consumed over a given period of time by an individual or a household. Since instruments for measuring actual food biodiversity in diets are missing, DD indicators may be used as a proxy. A limitation is related to the number and the choice of food groups. |
| <ul style="list-style-type: none"> Dietary Diversity Scores (DDS, also called “Dietary Variety Scores” or “Food Groups Scores”): the number of food groups consumed over a certain period of time among a list of foods groups Food Variety Score: the number of food items, including cultivars, consumed over a certain period of time | |
| <i>Species diversity consumed</i> | Consuming a variety of species contributes to healthy diets and supports more biodiverse agro-ecosystems. |
| <ul style="list-style-type: none"> Dietary species richness: a count of the number of species consumed by an individual per day Richness of species by food group consumed | |
| <i>Cultivar diversity consumed</i> | A count of the number of cultivars (varieties) within a given species consumed over a certain period of time |
| | This indicator could represent a precise measure of agrobiodiversity conservation through consumption. |

between different assessment dimensions need to be further investigated: for example, substituting cow milk by soy drink reduces the carbon and material footprint of e.g. pancakes (see [Speck et al., 2020](#))

for their assessment with the NAHGAST tool), but substituting EU-certified TSG hay milk by soy drink might negatively affect their biodiversity impact. Solutions to the issue of eventually higher costs for better-quality ingredients (e.g. adaptation of kitchen mixed-calculations) need to be developed in collaboration with practitioners as well.

7.2. Strengths and limits of the proposed DPSIR framework

The DPSIR model developed in this study proved to be useful for analysing and understanding the interactions in a complex system, which confirms the conclusions of previous studies ([Hou et al., 2014](#); [Santos-Martín et al., 2013](#)). Actually, the model is often criticized for representing a too simplistic and linear causal chain that ignores the complexity of reality ([Tscherning et al., 2012](#)). However, conceptual frameworks based on causality allow to clearly structure and organize information, supporting the understanding of complex issues. The usefulness of the DPSIR framework for the analysis of complex social-ecological systems has been shown ([Lewison et al., 2016](#)) and was confirmed in this study. Moreover, the model promotes a trans-disciplinary approach – particularly important to address wicked problems such as biodiversity-related issues, that require strategies integrating different approaches and kinds of knowledge ([Mehring et al., 2017](#)).

Another criticism frequently moved to the DPSIR model is that of being based on an anthropocentric perspective that considers the environment simply as a provider of ES ([Hou et al., 2014](#); [Binder et al., 2013](#)). In this study, a version of the DPSIR framework was developed in which biodiversity and ES were made explicit. A limit of the study might

be that of having considered mainly Pressures, States and Responses. However, the analysis and operationalization of the relationships between all the components of the DPSIR chain was not the objective of this work.

The analysis focused on a very specific sector, and this carries both positive implications and shortcomings. Biodiversity loss is caused by multiple factors, not only by the food system. The analysis of the problem in its entirety, however, was not the scope of this work. Moreover, agricultural production (driven by food consumption) is one of its most fundamental causes (Emmerson et al., 2016). Yet keeping in mind the broader picture is necessary: for example, Responses to certain Drivers and Pressures in one sector might affect other sectors as well. The single elements of one DPSIR chain have multiple interactions that might often go beyond the boundaries of their system, and local actions based on partial understanding may have unexpected consequences on higher levels (Gregory et al., 2013).

Finally, the factors negatively affecting biodiversity are rather well known on the macro level, while less is known about their interactions on smaller scales. The analysis carried out can improve the understanding of dynamics and processes on a lower (single business) level. Lewison et al. (2016) suggest to include in the DPSIR framework also “operational level actors” such as companies, as this could promote innovative responses. The application of the DPSIR model developed in this study goes in this direction. Moreover, the analysis presented here promotes Responses addressing indirect Drivers (consumption) and not only Pressures (agricultural production) – while Responses usually address Pressures and only rarely Drivers (which, however, are the forces beyond them), and DPSIR-based analyses often do not promote proactive strategies actively seeking to protect biodiversity (Kelble et al., 2013). The indicators proposed in this study and in the NAHGAST project are conceived to trigger proactive behaviours and future-oriented strategies.

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CRedit authorship contribution statement

Silvia Monetti: Conceptualization, Methodology, Software, Formal analysis, Investigation, Data curation, Writing - original draft, Visualization, Supervision. **Michael Pregernig:** Conceptualization, Methodology, Validation, Visualization. **Melanie Speck:** Conceptualization, Methodology, Validation, Data curation, Writing - original draft. **Nina Langen:** Validation, Writing - review & editing. **Katrin Bienge:** Validation, Data curation, Writing - original draft.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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